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MOKE investigation of silicide films ion-beam synthesized in single-crystal silicon

G.G. Gumarov [a,b,*], V.Yu. Petukhov [a,b], A.I. Gumarov [b], R.A. Khalikov [a], D.A. Konovalov [a], V.F. Valeev [a], R.I. Khaibullin [a,b]

[a] Zavoisky Physical-Technical Institute of RAS, Sibirsky tract 10/7, 420029 Kazan, Russia
[b] Kazan (Volga Region) Federal University, Kremlyovskaya St. 18, 420008 Kazan, Russia

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ABSTRACT

Magnetic-field-assisted ion-beam synthesis was used to produce thin magnetic films. Si wafers were implanted with 40 keV Fe^+ ions with a fluence of 3×10^{17} cm^{-2} in the external magnetic field of 9.6×10^4 A/m. The samples were investigated by scanning magneto-optical Kerr effect magnetometry, inductive magnetometry and reflection high-energy electron diffraction. The main synthesized phase was ferromagnetic Fe_3Si. In some regions of the samples the deviations of the easy magnetic axis near the applied magnetic field were revealed. These local changes can be caused by various reasons: the presence of mechanical stresses in a silicon substrate during the ion bombardment, the appearance of temperature gradients, inhomogeneous sputtering and the appearance of small magnetic fields in the chamber of the accelerator.

1. Introduction

The study of the induced magnetic anisotropy in ferromagnetic thin films is of significant importance both for fundamental science and for practical applications. Usually the uniaxial anisotropy in ferromagnetic alloys is induced by applying magnetic saturation fields during film deposition or by subsequent thermomagnetic treatment. Recently, the alteration of magnetic properties in magnetic thin films by ion irradiation in external magnetic field has gained increased attention [1–7]. This technique is especially useful as it also can be used to locally alter magnetic properties like saturation magnetization, magnetic anisotropy and etc. [7].

Earlier we used magnetic-field-assisted ion-beam synthesis to produce thin films of ferromagnetic silicide Fe_3Si in single-crystal silicon substrates [8]. The samples were investigated by Mössbauer spectroscopy, X-ray diffraction and autodyne method. The obtained thin films consisted of ferromagnetic Fe_3Si and a small amount of nonmagnetic FeSi phases. Other phases were not detected. It was shown that application of the magnetic field during the high-dose Fe ion implantation led to the pronounced in-plane magnetic anisotropy in the synthesized films. The observed anisotropy was a superposition of the magnetocrystalline anisotropy of cubic Fe_3Si and induced uniaxial anisotropy. The observed angular dependence of in-plane magnetic susceptibility measured by autodyne method was described on the basis of the Stoner–Wohlfarth model. The general features of the calculated curves are in good agreement with the experiment but the obtained results should be averaged over the sizes and the orientations of different clusters in the films.

The goal of the present work is to closely investigate the magnetic properties of thin silicide films ion-beam synthesized in single-crystal silicon in external magnetic field using the magneto-optical Kerr effect (MOKE). In addition, this method allows studying local magnetic in-plane characteristics.

2. Experimental

40 keV Fe ions were implanted into (1 1 1) single-crystal silicon wafers at room temperature. The implantation fluence was 3×10^{17} cm^{-2}, the ion current density being about 4 μA/cm^2. The external magnetic field H_i of 9.6×10^4 A/m was applied parallel to the sample surface during implantation.

Reflection high-energy electron diffraction (RHEED) was used for investigation of the phase composition and the texture of the synthesized films. The RHEED gun was operated at 75 kV primary voltage, the pattern was recorded at room temperature.

The integral magnetic properties of the films were investigated using an induction magnetometer. A dependence of the magnitude of the induced magnetic moment on the value of the magnetic field applied in the sample plane was registered at the magnetic field sweep up to 500 mT. While processing the results of magnetic

* Corresponding author at: Zavoisky Physical-Technical Institute of RAS, Sibirsky tract 10/7, 420029 Kazan, Russia. Tel.: +7 843 272 12 41; fax: +7 843 272 50 75.
E-mail addresses: gumarov@kfti.knc.ru (G.G. Gumarov), petukhov@kfti.knc.ru (V.Yu. Petukhov), amirgumarov@rambler.ru (A.I. Gumarov), khalikoff@gmail.com (R.A. Khalikov), dak@kfti.knc.ru (D.A. Konovalov), rik@kfti.knc.ru (V.F. Valeev), rik@kfti.knc.ru (R.I. Khaibullin).

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